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MULTILAYER MICROSTRUCTURAL DEVICE

The field of the invention

The present invention relates to a multilayer microstructural device and in particular to a multilayer microstructural device comprising mating alignment structures.

Background of the Invention

Optical fibers provide key elements for modern telecommunication systems. In order to couple light into and out from fibers, highly efficient fiber/waveguide connectors need to be developed

Optical fibers have for many years been used in long-haul distance information transportation, e.g. in the optical backbone network between major cities. As the distance between transmitters and receivers is shortened, the need for low-cost waveguide connectors has increased. For instance, in Fiber-to-the-Home (FTTH) applications a device connecting one or several optical fibers with the end user can be compared to consumer products such as telephone jacks.

Several types of waveguide connections fabricated with etched silicon chips as substrate/carrier have been reported. Silicon chips, however, are expensive to produce and are liable to break under the high pressures which they will be subjected to when pressing waveguide connections. In order to enable fiberoptic connectors to be used on a large scale, micromachined connectors must be able to compete strongly with existing solutions, especially with regard to cost.

Fortunately, almost all microstructures that are possible to produce technically in silicon can be replicated in plastic materials. Since replication is not in itself an expensive process, there is available an economic leeway which will enable the use of advanced micro electro mechanical system (MEMS) manufacturing equipment,

e.g. photolithography, litografie agalvano abformung (LIGA) techniques, electron-beam lithography etc.

Distinct from silicon, plastic has good dielectric properties. The plastic may be transparent, which can be beneficial in the case of integrated optics. Plastic is also a cheaper material than silicon.

Replicated polymeric substrates can be used in the construction of fibre optic transmitter/receiver modules having microstructures such as fibre aligning grooves, optofibres and semiconductor components such as PIN diodes, LEDs, Vertical-cavity surface –emitting lasers (VCSELs), amplifiers, drive electronics, integrated circuits and so on. The substrate may also contain integrated micro-optical surfaces for advanced beam shaping of the light being coupled, such as diffractive optical elements (DOEs), which can be designed to harness light in a desired manner.

By utilizing micromachining techniques, miniaturized connectors can be realized and replication technology can then be used to produce low-cost devices in plastic materials

To achieve desired mechanical or optical features one or more replicated elements often are bonded on top of each other forming a layered structure. The different layers then may have different functions. US 5,984,534 discloses a double layer microstructural device comprising a first layer with V-grooves for accommodating optical fibers and a second layer acting as a lid and retainer for the optical fibers.

Many times it is of great importance that the layers in a multilayer microstructural device are aligned relative to each other with high precision. Alignment can either be obtained by formation of alignment structures in facing surfaces of successive layers or by an active aligning step in the assembly procedure. However, it is difficult to achieve a high degree of alignment precision using existing alignment structures, why additional active alignment often is required, and active alignment is time consuming and therefore expensive.

Summary of the Invention

The object of the invention is to provide a new multilayer microstructural device, which overcomes the drawbacks of the prior art multilayer microstructural devices. This is achieved by the multilayer microstructural device as defined in claim 1.

One advantage with the multilayer microstructural device is that improved aligning accuracy is achieved by mating alignment structures, eliminating the need for active alignment to achieve high precision aligning.

Another advantage is that the process for manufacturing the multilayer microstructural device is a low cost process.

Still another advantage is that both layers in a double layer microstructural device are produced from one single master.

Embodiments of the invention are defined in the dependent claims.

Brief Description of the Drawings

The invention will be described in detail below with reference to the drawings, in which:

Fig. 1 shows a schematic view of a multilayer microstructural device according to the present invention.

Fig. 2a shows a top view of a master layout for producing a multilayer microstructural device according to the present invention.

Fig. 2b shows a cross sectional view along A-A of a positive replication of the master layout of fig 2a.

Fig. 2c shows a cross sectional view along A-A of a negative replication of the master layout of fig 2a.

Detailed Description of Preferred Embodiments

Generally, the multilayer microstructural device according to the present invention comprises at least a first and a second micro-replicated layer. The layers may be formed by injection molding of a polymeric material such as polycarbonate or the like. However, other methods of producing micro-replicated layers may also be used, such as replication using UV-curable polymers and the like. To obtain the desired mechanical or optical features the layers are aligned relative to each other by mating alignment structures. To achieve a high degree of alignment precision, the layers are formed such that the first layer is a positive replication of a microstructural master, the second layer is a negative replication of the same microstructural master, and that each pair of mating alignment structures originates from the same microstructural element on the master.

The features of the multilayer microstructural device according to the present invention will now be is described more in detail in the form of an optofiber waveguide connection, but it should be understood that the multilayer microstructural device according to the invention can be adapted to numerous situations where high precision alignment of two or more layers in a multilayer microstructural device is required.

Fig. 1 shows a schematic picture of a fiber connector 10 comprised of a first or upper layer 20a and a second or lower layer 20b. The fiber connector 10 further comprises alignment structures 30a, 30b formed in the first and second layer 20a, 20b respectively. A V-groove 40 is formed in the second layer 20b and is adapted to hold an optical fiber 50 in place. The V-groove 40 has a sloped end-facet 60 in that is used to reflect light from the optical fiber 50 onto a micro-optical surface 70, such as a transmissive diffractive element, formed in the first layer 20a.

The connector could for instance be used in a dense wavelength-division multiplexing (DWDM) system, where different wavelengths transported through the fiber could be split to reach different receivers. For symmetry reasons the opposite

case, where light from different transmitters are coupled into the same optical fiber 50, can just as well be realized.

As mentioned above, the improved alignment that is obtained according to the invention rely on that the alignment structures 30a,b of the first and the second layer 20a,b respectively originate from the same structure on one single master 100. Figs. 2a and 2c shows the master-layout 100 by which this is achieved. Fig. 2a is a top view of the master-layout 100 of the connector 10. Fig. 2c is a cross sectional view of fig 2a along A-A. As can be seen from the figures, all structures in the master 100 are negative (concave), whereas fig. 2b shows a positive (convex) replication 110 of the master.

As is shown in fig. 2b, the first layer 20a in the connector 10 is represented by the section to the left of C-C in the positive replication 110 of the master 100. As is shown in fig. 2c, the second layer 20b in the connector 10 is represented by the section to the right of B-B in the negative replication 120 of the master. Hence, when the two layers 20a and 20b are put together, the mating alignment structures 30a,b originate from the same structure on the master 100, whereby they will fit perfect into each other.

As is clear from figs 2b and 2c, the layer 20a has to be rotated relative an axis of rotation D-D in fig 2a before it is fitted on top of the layer 20b. Due to this rotation the shape of the mating alignment structures 30a,b is restricted to structures that are symmetric about a central mirror plane with a normal parallel with A-A in fig 2a.

The fabrication of the connector 10 was done by the following process.

Firstly a master 100 in the form of a silicon wafer 100 is produced. The master 100 comprises a large number of sections representing the layers 20a,b of the connector 10. The number of layer sections on each master wafer 100 is determined of the size of each connector layer 20a,b. Each connector layer section 20a,b is formed in the master wafer 100 by the following steps:

a. Formation of the micro-optical surface 70 in the silicon wafer 100, crystal plane (100), by direct-write electron-beam lithography in a photo resist layer applied on the surface of the silicon wafer 100, followed by plasma dry etching. Hence, the surface relief of the micro-optical surface 70 is transferred into the surface of the silicon wafer 100 The micro-optical surface 70 may be of several different types, such as a collimating Fresnel lens, an off-axis diffractive lens or a fan-out element.

b. Deposition of a silicon nitride layer onto the wafer 100.

c. Formation of V-grooves 40 and alignment microstructures30a,b by photolithography followed by nitride plasma etching and wet etching of the silicon in KOH.

d. Stripping of the remaining nitride by wet etching.

Hence, one and the same master 100 comprises both deep structures 30a,b,40 for later fiber alignment and self-alignment of the double layer structure as well a micro-optical surface 70 for beam steering, all aligned relative each other with the available accuracy of the lithography steps.

Thereafter, two copies of the structured silicon master 100 are created by electroplating in nickel, a first copy with the same polarity as the master 100 (having concave structures) and a second copy with opposite polarity (containing convex structures). The process of making master copies by electroplating in nickel is well known in the art of micro replication and will therefore not be described in detail herein.

The two nickel copies are hereafter used as mould surfaces for injection moulding of first and second polycarbonate plastic discs. The second plastic disc has the same polarity as the master 100 (having concave structures) representing the second layer 20b in the connector 10. Hence the first plastic disc has opposite polarity (containing convex structures) representing the first layer 20a in the connector 10.

The molded discs are thereafter diced into connector layer sections 20a,b. And the second connector layer sections 20b which shall reflect light from the optical fiber towards the micro-optical surface are metallized.

Finally, the first connector layer sections 20a are arranged on top of the corresponding second connector layer sections 20b, with optical fibers placed in the V-grooves, and bonded together.

As the connector layer sections 20a,b comprises mating alignment structures 30a, 30b that originates from the same structures on the master 100 the alignment precision will be in the order of the precision in the lithography steps.

The obtainable alignment precision has been evaluated using connector layer sections 20a,b put together without on additional alignment than the mating alignment structures. A microscope was used to measure the resulting alignment accuracy for a number of connectors 10 and the measurements showed that the obtainable aligning accuracy was slightly lower (about ± 5μm) than the alignment precision of the lithography steps which in this case was roughly estimated to ± 2μm.

CLAIMS:

1. Multilayer microstructural device (10) comprising a first and a second layer (20a, 20b), which layers (20a, 20b) are aligned relative to each other by mating alignment structures (30a, 30b), **characterized in** that

   the first layer (20a) is a positive replication of a microstructural master (100) comprising a number of microstructural elements (30a, 30b, 40, 70),

   the second layer (20b) is a negative replication of the same microstructural master (100),

   that each pair of mating alignment structures (30a, 30b) originate from the same microstructural element (30a, 30b) on the master (100).

2. Multilayer microstructural device (10) according to claim 1, **characterized in** that the microstructural master (100) comprises at least one deep microscale structure (30a, 30b, 40) and at least one shallow surface relief (70), which are aligned relative to each other by said maiting alignment structures (30a, 30b).

3. Multilayer microstructural device (10) according to claim 2, **characterized in** that the deep microscale structure is a fibre aligning groove (40).

4. Multilayer microstructural device (10) according to claim 2, **characterized in** that the shallow surface relief is a diffractive structure (70).

ABSTRACT

Multilayer microstructural device (10) comprising a first and a second layer (20a, 20b), which layers (20a, 20b) are aligned relative to each other by mating alignment structures (30a, 30b). The first layer (20a) is a positive replication of a microstructural master (100) comprising a number of microstructural elements (30a, 30b, 40, 70), the second layer (20b) is a negative replication of the same microstructural master (100), and each pair of mating alignment structures (30a, 30b) originate from the same microstructural element (30a, 30b) on the master (100).

Fig. 1

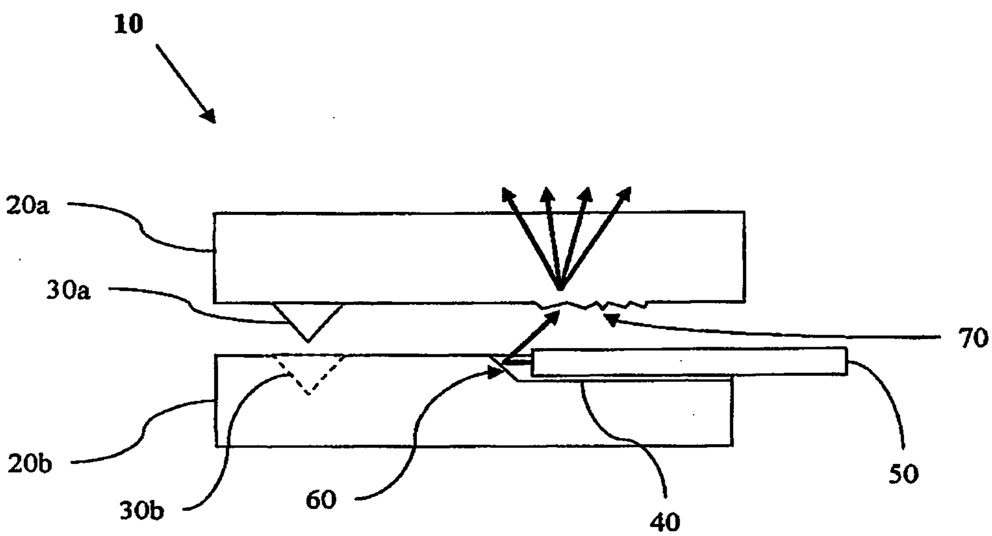

Fig. 1

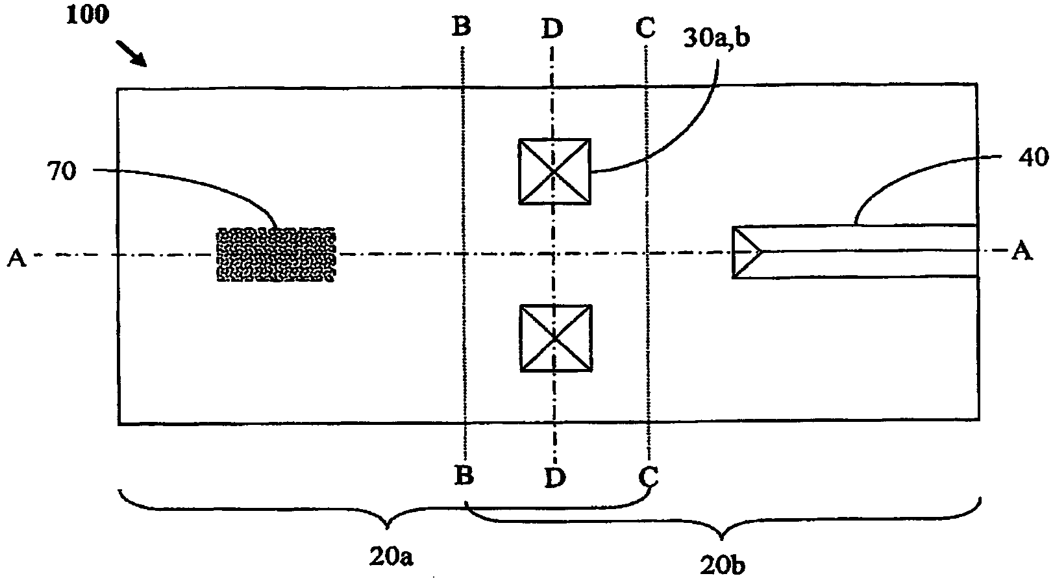

Fig. 2a

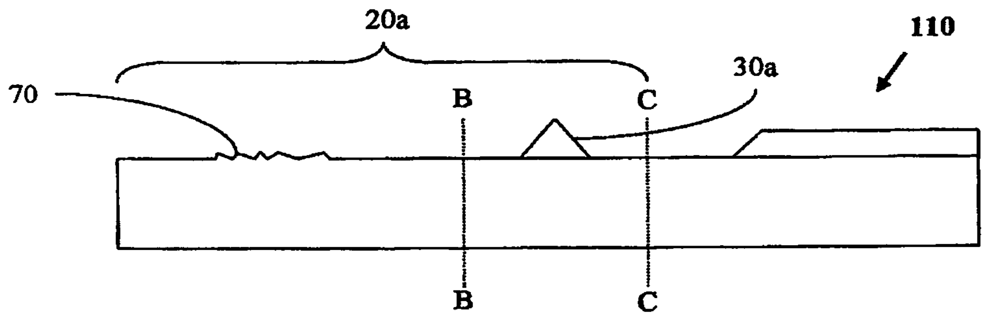

Fig. 2b

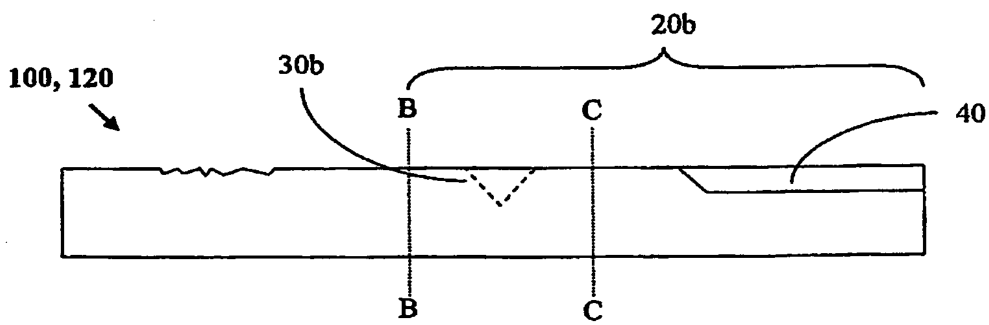

Fig. 2c